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## *Assessment of Nonlethal Unmanned Aerial Vehicles for Integration with Combat Aviation Missions*

*Monti Callero*

**Arroyo Center**

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## *Assessment of Nonlethal Unmanned Aerial Vehicles for Integration with Combat Aviation Missions*

*Monti Callero*

*Prepared for the  
United States Army*

*Arroyo Center*

*DB-120-A*

## PREFACE

This documented briefing assesses nonlethal unmanned aerial vehicles (UAV) for integration with combat aviation missions. It develops concepts of employment for UAVs to directly participate in primary combat aviation operations, including scouting and reconnaissance, attack, security, and air assault. Of particular interest was the "Bird Dog" concept, wherein a crew on the aviation team exercises positive control over the UAV during the mission. Our assessment focused on the operational and command and control aspects of integrating the UAV into these missions, and this documented briefing primarily discusses operational effectiveness and survivability of integrated UAV operations under various modes of mission integration. It also discusses UAV characteristics that would best support these modes, including vertical takeoff and landing (VTOL) and non-VTOL capability.

This work was done for the Arroyo Center Project on Unmanned Aerial Vehicle Assessment sponsored by the Executive Director, Aviation Research, Development, and Engineering Center, Aviation and Troop Command, and performed for the Arroyo Center's Force Development and Technology Program. The Arroyo Center is a federally funded research and development center sponsored by the United States Army.

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## SUMMARY

Unmanned aerial vehicles (UAVs) provide potentially important advantages over manned systems in the conduct of scout, reconnaissance, and surveillance operations over enemy-controlled territory. These advantages are generally considered to include avoiding the personal and political penalties of death or capture of crew members, employing relatively inexpensive platforms that could be considered expendable under certain high-payoff operational conditions, frustrating air defenses with their small size to achieve greater survivability than their manned counterparts, and providing a more cost-efficient operation from the standpoint of acquisition, sustainability, deployability, and operating environment requirements. Typically, UAVs operate independently of other systems. The Army is interested in the potential for UAVs to contribute directly to combat aviation missions; how that contribution could be achieved; and what the implications would be for UAV and helicopter characteristics and for operational tactics, techniques, and procedures. This research developed concepts of employment for UAVs integrated with primary combat aviation missions, including scouting and reconnaissance, attack, security, and air assault. Of particular interest was the "Bird Dog" concept, wherein a crew on the aviation team exercises positive control over the UAV during the mission. Assessments and conclusions presented in this briefing are primarily based on qualitative analyses from which we intended to provide an informed basis for determining the most critical issues that need comprehensive analyses.

Three integration modes can support mission requirements—associated, dedicated, and coupled. In the associated mode, the UAV would support the combat aviation team through preplanned mission tasking specified in an operations order; mission results would be passed to the mission team through normal communications. In the dedicated mode, the UAV would be assigned to the singular task of supporting the combat aviation mission throughout the duration of the mission. The mission team would exercise indirect, non-realtime operational control of the UAV through a remote UAV control facility. The coupled mode, which reflects the Bird Dog concept, would place the UAV under the positive realtime maneuver and functional control of a combat aviation team aircraft. Clearly, the responsiveness and usefulness to the mission commander's requirements increase with the directness of the missions control, but consideration must be given to the crew work load and, in the coupled mode, to the possible need to add an aircraft to perform the UAV control function. In

any control mode, the UAVs can operate overhead above the area or close to the ground, which becomes a factor in their survivability and influences their design characteristics.

Two factors that affect the UAV's mission contributions are the capabilities of its sensors and its ability to survive in an air defense environment. Our assessment indicates that future UAVs will need improvements over today's fielded systems in both of these categories to reach their mission support potential. Assuming these capabilities reach acceptable levels, integrated UAV contributions begin in the preplanning phase with premission reconnoitering of the operating area, continue through the ingress (if penetration of enemy territory is required), intensify during mission execution, and follow up supporting the egress. An important general contribution to all missions is the enhancement of situation awareness and location of threat systems that the UAV can provide the mission commander. This information leads to overall greater efficiency in conducting the mission and directly affects the survival of the mission team since the mission can be adjusted in advance to minimize threat system exposure. Additionally, the UAV can share directly in many mission tasks, such as performing scout, reconnaissance, and targeting functions.

Detailed qualitative assessment of each of the missions indicated that *coupled* (Bird Dog) is the preferred integration mode for all combat aviation missions and is required for attack and air assault. Use of the coupled mode for scout/recon depends critically on the development of the necessary technology and operator interfaces to minimize the additional work load on the UAV control aircraft crew so as not to increase the team size while maintaining full UAV exploitation and the two-aircraft scout/recon team capability. We consider it operationally untenable to add a control aircraft to a two-aircraft scout/recon team. For the security mission, coupled integration permits a cavalry unit to screen and cover multiple areas by operating a UAV in each area and not launching until a situation is observed that demands human attention.

Our preliminary assessment of the tactical UAV leads us to expect that combat aviation missions could be significantly enhanced if a UAV were integrated as a full member of the mission team. Effectiveness would improve both in the results that the mission achieves and in the efficiency with which the aviation systems can be employed. Survivability of the aviation systems may also result both by being able to use the UAV information to avoid or destroy air defenses and by reduced exposure on the battlefield because of the more efficient manner in which the mission can be conducted. Efficiency also leads to better overall aviation resource

utilization, which would increase the resources available for other missions.

To realize the benefits of integrated UAV operations, a number of technological improvements need to be incorporated into future advanced UAV designs. Compared with today's capability, the mission equipment package needs expanding to contain more sensors and functions, including radar warning that can be relayed to the mission team, laser ranger/designator, digital mapping (for vertical takeoff and landing [VTOL]), and perhaps millimeter wave radar. Also, the imaging sensor needs enhancement to increase the scope and precision of its viewing area. And features must be added so that the UAV's survivability is highly likely in the face of advanced air defenses and virtually assured when operating in lesser, more likely air defense environments.

The VTOL near-earth and nap-of-the-earth (NOE) flight capabilities appear repeatedly in our assessments to be necessary to mission accomplishment, both to support the operation and to use terrain masking to survive in high-threat areas. To maintain its effectiveness in supporting high-speed helicopter transits, ingresses, and egresses, the UAV must have even greater speed capability, perhaps two to three times as great as that of the helicopters. The apparent operational advantages of VTOL are significant, particularly those of the tilt-rotor design, which currently exceeds fixed-wing UAV performance at altitude, provides the very low level and NOE capability, and achieves the speed requirement. A VTOL UAV's ability to use the same basing modes and to operate in the same flight regimes as the combat aviation mission teams provides close coordination of all phases of integrated missions. The Eagle-Eye tilt-rotor UAV prototype developed under the Joint UAV program demonstrates the feasibility of a tilt-rotor UAV.

We recommend that specific analysis be directed at UAV sensor performance and survivability, near-earth operation feasibility, and airborne interface system requirements. Further, of top priority, a quantitative analysis of how integrating UAVs would change the operational effectiveness of combat aviation forces is essential to formulating a position on UAV development. An analysis would credibly establish the potential benefits and identify the technological and operational conditions under which the benefits accrue. Analytical tools exist that could be applied to this task. For research into operations like integrated UAV missions that have little or no practical experience base, operator interactive analytical systems provide an environment to experiment with and develop tactics and procedures before committing them to specific behaviors in an analysis. The available interactive systems include the Aviation Test Bed at Fort Rucker and contractor's

research and development simulators, although simulators suffer from combat environment fidelity problems and are not readily adapted to analysis. RAND's Combat Analysis Environment probably offers the most adaptive and efficient high-resolution, operator-interactive analytical system available. Noninteractive systems also exist that use programmed rules to represent stylized operator behavior (SAVVIE) or low-fidelity, nonreactive behavior (JANUS and CASTFOREM).

## GLOSSARY

|           |   |
|-----------|---|
| AGL       | Above ground level  |
| AH        | Attack helicopter   |
| ASE       | Aircraft survival equipment   |
| AVTB      | Aviation Test Bed   |
| BP        | Battle position   |
| C2        | Command and control   |
| C3        | Command, control, and communications  |
| CAE       | Combat Analysis Environment (located at RAND)   |
| CASTFOREM | An Army combat simulation model with weapon systems' interaction level of detail (Ref. 1) |
| ECCM      | Electronic counter-countermeasures  |
| ECM       | Electronic countermeasures  |
| FAADS     | Forward-area air defense system   |
| FARP      | Forward arming and refueling point  |
| FLIR      | Forward-looking infrared system   |
| FOV       | Field-of-view   |
| FW        | Fixed-wing  |
| IR        | Infrared  |
| JANUS     | An Army combat simulation model with weapon systems' interaction level of detail (Ref. 3) |
| LOS       | Line-of-sight   |
| LZ        | Landing zone  |
| MEP       | Mission equipment package   |
| MMW       | Millimeter wave   |
| MOE       | Measure of effectiveness  |
| NAI       | Named area of interest  |
| NOE       | Nap-of-the-earth  |
| OA        | Operating area  |
| OP        | Observation position  |
| RF        | Radio frequency (i.e., radar)   |
| RPV       | Remotely piloted vehicle  |
| SAVVIE    | An Army combat simulation model with weapon systems' interaction level of detail (Ref. 2) |
| TV        | Television  |
| UAV       | Unmanned aerial vehicle   |
| UH        | Utility helicopter  |
| VTOL      | Vertical takeoff and landing  |

# **ASSESSMENT OF NONLETHAL UNMANNED AERIAL VEHICLES FOR INTEGRATION WITH COMBAT AVIATION MISSIONS**

**The Arroyo Center  
RAND**

## **INTRODUCTION**

Unmanned aerial vehicles (UAVs) provide potentially important advantages over manned systems in the conduct of scout, reconnaissance, and surveillance operations over enemy-controlled territory. These advantages are generally considered to include avoiding the personal and political penalties of death or capture of crew members, employing relatively inexpensive platforms that could be considered expendable under certain high-payoff operational conditions, frustrating air defenses with their small size to achieve greater survivability than their manned counterparts, and providing a more cost-efficient operation from the standpoint of acquisition, sustainability, deployability, and operating environment requirements. Typically, UAVs operate autonomously by automatically following on-board guidance and control profiles and/or semiautonomously by reacting to realtime mission profile inputs from monitor and control personnel. The United States and other nations, most notably Israel, have conducted wartime UAV operations with reportedly good results.

Of interest to the Army aviation community is the potential for UAVs to contribute directly to combat aviation missions, how that contribution could be achieved, and what the implications would be for UAV and helicopter characteristics and for operational tactics, techniques, and procedures. To begin to address these questions, the Arroyo Center has conducted a qualitative assessment of the principal issues. This documented briefing is the final report for that project.

## Research Objectives

- **Develop concepts of employment for nonlethal UAV to support combat aviation missions**
  - Scout, recon, attack, security, air assault
  - Bird Dog and indirect control
- **Identify and discuss**
  - Operational and C2 issues
  - Concept-driven UAV characteristics (including VTOL)
  - Organizational and logistical issues
- **Determine key areas for further analysis and technical development**

This research aimed to develop concepts of employment for UAVs to directly participate in primary combat aviation operations, including scouting and reconnaissance, attack, security, and air assault. Of particular interest was the "Bird Dog" concept, wherein a crew on the aviation team exercises positive control over the UAV during the mission, compared with the team indirectly controlling the UAV through a remote intermediary control station either on the ground or in the air. Our assessment focused on the operational and command and control aspects of integrating the UAV into these missions, and this briefing primarily discusses operational effectiveness and survivability of integrated UAV operations under Bird Dog and other modes of mission integration. It also discusses UAV characteristics that would best support them, including vertical takeoff and landing (VTOL) versus non-VTOL.

The preliminary assessments and conclusions presented in this briefing are primarily based on qualitative analyses from which we intended to surface and address a large number of issues pertaining to nonlethal UAVs and to provide an informed basis for determining the most critical issues that need comprehensive analyses.

## Premises

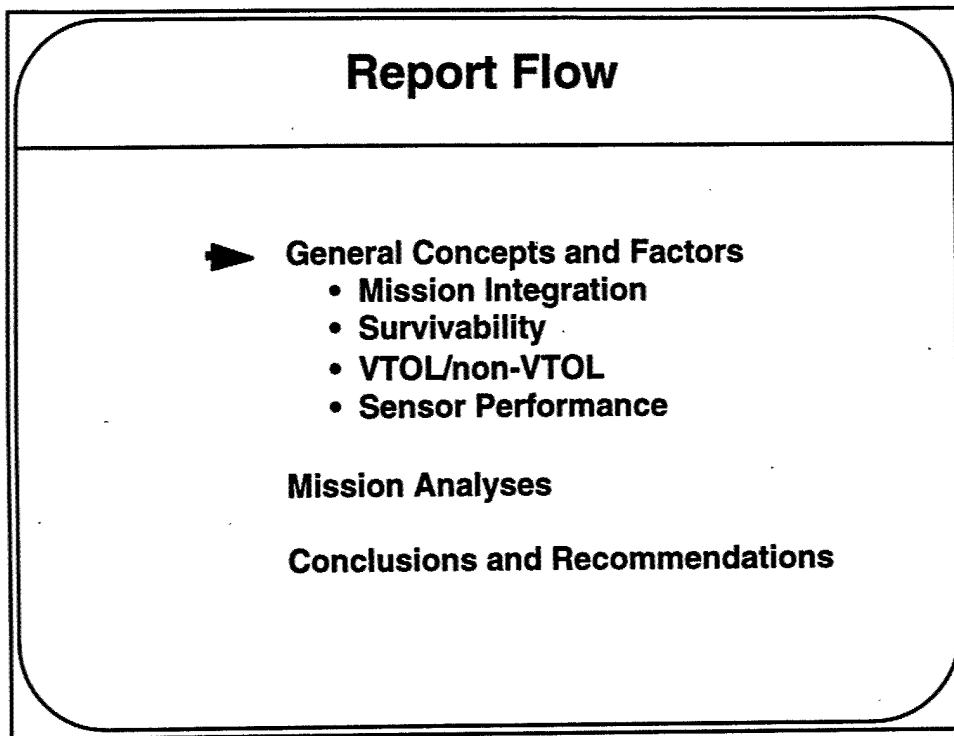
- **Seek “major” operational contributions**
  - New capabilities (achievable only with UAV integration)
  - Significantly increase mission effectiveness
  - Significantly reduce attrition
- **“Sacrificial” UAV operations not tenable**
  - Low attrition of UAV is a key objective
  - Reduced helo attrition derives from improved operational capabilities and/or doctrinal alternatives
- **Exogenous analyses would include**
  - Development and aquisition costs
  - Life-cycle costs (incl combat aviation fleet cost implications)
  - Personnel factors (incl casualty minimizing)
  - Deployability and sustainability
  - Peripheral missions

We established certain premises to clarify the research direction. First, the research seeks to identify UAV contributions that would change the operational calculus of combat aviation missions along some important dimension such as mission effectiveness, conservation of force, survivability (itself partially a conservation of force factor), or responsiveness.

Second, the casually popular notion of using a UAV in a deliberately sacrificial manner (e.g., to draw fire) was not considered a tenable tactic. Although UAVs may be the system of choice for particularly risky but unavoidable maneuvers consistent with both operational and fiscal realities, UAV survivability matters. Losing a UAV may be better than losing a manned aircraft, but losing neither is preferred. Operational situations could exist in which a single UAV on the team may contribute more to mission success and overall survival of the team than any single manned aircraft. Further, regardless of the UAV's greatly lower cost compared with manned systems, we can expect that the limited numbers actually procured would result in the preservation of the fleet being a critical operational factor. Hence, we feel that low attrition is an essential element of the viability of the UAV as an active, integrated member of a combat aviation team, or for that matter, in any battlefield role. Low

attrition may also defuse a polarization of the UAV development and acquisition debate.

Finally, we wanted to recognize the existence of a list of important considerations that did not fall within the scope of this mission-oriented assessment but would need to be comprehensively addressed as a matter of course to properly analyze the alternative systems and operational modes that the research develops.



In this briefing, we first discuss general concepts and issues that would affect the integration of a UAV into a combat aviation mission. We then cover the mission analyses that provide the operations base for integrating the UAV on each mission team and then discuss major systems and operations implications that emerge from those analyses and indicate where further analyses must be done. Finally, we summarize our findings and suggestions for future analyses.

## Integration Modes

- **Associated**
  - UAV supports combat aviation team via mission tasking
  - Control executed through UAV command station (land or air)
  - Prefer at least one team member with video-receptor capability
- **Dedicated**
  - UAV under operational control of combat aviation team
  - Indirect, non-realtime control by combat aviation team executed through mission remote UAV command station (land or air)
  - At least one team member with video-receptor capability
- **Coupled (Bird Dog)**
  - UAV under direct, realtime control of combat aviation team
  - Close proximity operations
  - Requires at least one UAV control/exploitation-capable team member

To help in conceptualizing and discussing integrated UAV/helicopter missions, we define three modes in which the integrated team could operate. During any particular mission, one or more of the modes could be used as appropriate to different mission phases.

At the lowest level of integration, *associated*, the UAV would support the combat aviation team through preplanned mission tasking specified in an operations order or more direct communications between the team and the UAV unit. The UAV unit would be responsible for operating the UAV in a manner that provides the specified support at the specified times.<sup>1</sup> It would be preferred that realtime UAV images be displayed in at least one of the mission aircraft for ready use by the mission commander, in which case at least one of the mission aircraft would require video receptor-recorder-playback capability. Alternatively, the UAV controllers could pass information received from the UAV to the mission aircraft using

<sup>1</sup>The current Army Hunter UAV operation utilizes a mission commander and target exploiter located in a command station that makes all decisions and directs UAV controllers, located in a separate mission control facility, about specifically what the UAV is to do; the controllers then take the necessary actions to control the UAV flight profile and sensors to accomplish the assigned tasks.

voice or digital communications. Again, communications support between nap-of-the-earth (NOE) aircraft and the UAV and the UAV command station would be required.

In the *dedicated* mode, the UAV would be assigned to the singular task of supporting the combat aviation mission, as called upon, throughout the duration of the mission, including the pre- and postmission phases. The combat aviation mission team would exercise indirect, non-realtime operational control of the UAV, executed through a remote airborne or ground-based UAV command station and/or control facility. The mission team would specify by voice or digital communications what tasks they wanted the UAV to perform (e.g., particular route or area reconnaissance), and UAV operators would take action to achieve that request. At least one of the mission aircraft would require video receptor-recorder-playback capability so that the UAV sensor images could be displayed in realtime or reviewed for use by the mission commander. This mode would also require the communications support needed to provide continuous sensor inputs to the mission aircraft operating NOE and direct communication between the mission aircraft and the UAV command station and/or control facility.

The highest level of integration, *coupled*, would place the UAV under the positive realtime maneuver and functional control of a combat aviation team aircraft. Although the control technique used in the coupled mode could conceivably be the same as that in a remotely piloted vehicle (RPV) wherein the controller actually flies the RPV with power and flight control commands (e.g., stick and throttle), the state-of-the-art UAV control technology provides the capability for issuing higher-order mission-task commands that the UAV would respond to in a semiautonomous manner. Such commands currently include mission equipment operation (e.g., sensor pointing and adjusting) and flight maneuvering (e.g., fly to a specific position and assume a given flight pattern) or a combination of both (e.g., reconnoiter a given geographical location or area). For VTOL operating very near the surface, commands could also include hover, mask, or bob-up, and terrain clearance restrictions between way-points. The coupled mode requires that at least one of the combat aviation team aircraft be equipped with the electronics, display, and control devices needed to control the UAV and to exploit the information the UAV sensors obtain. The coupled mode reflects the essence of the *Bird Dog* concept.

## Top-Level Observations on UAV Integration Modes

- **Associated**
  - >>Permits flexible UAV structure & operating environment
  - <<Expect nonprecision/low-responsiveness integration
- **Dedicated**
  - >>Permits non-mission-compatible UAV control system
    - maintains doctrinal team composition
  - <<Introduces task specification and execution complexity
    - communications and communicating
  - <<Limits precision/timeliness of integration
- **Coupled**
  - >>Permits precise integration of UAV with fires/maneuvers
  - <<Requires mission-compatible specialized system
    - affects team size or crew work load

Each of the three integration modes has positive and negative aspects whose relative importance could well be mission-dependent. At this point, we will only surface those aspects and comment on the operational issues/questions that they present and will qualitatively assess them later in the context of particular missions.<sup>2</sup> Clearly, for an integration mode to be viable, its negative factors would have to be overcompensated for by improved mission results, greater force survivability, and/or better utilization of aviation resources and investments.

The *associated* mode has the singular advantage of permitting maximum flexibility and efficiency in the UAV organization's structure and operation to support all of its UAV mission requirements in the conflict area. The associated mode permits UAV integration without affecting mission team configuration or requiring a specially equipped and crewed mission-compatible aircraft, although one of the mission aircraft having

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<sup>2</sup>It is necessary to recognize that although qualitative assessments provide important insights into the issues, follow-on work using quantitative analytical techniques, models, and simulations would be required to more closely and credibly determine the relative benefits from the different integration modes and to examine alternative concepts for implementing them in practice.

the capability to receive and display the UAV sensor images/information may improve the ability of the mission team to utilize the UAV inputs during mission execution. However, with regard to combat aviation mission integration, the associated mode's preplanned nature and potentially poor responsiveness to changing mission conditions could significantly limit the mission support functions the UAVs could perform.<sup>3</sup>

The *dedicated* mode permits UAV integration without affecting mission team configuration or requiring a specially equipped and crewed mission-compatible aircraft, although one of the mission aircraft should have the capability to receive and display the UAV sensor images/information. However, because the mission team controls UAV actions indirectly through remotely located UAV controllers, the dedicated mode could lack precision and timeliness of integration, a shortcoming that could be an important factor in mission effectiveness. Also, the remote location of the UAV controllers places crucial demands on the communications capability and communicating procedures needed to maintain responsive mission team/UAV integration.

The *coupled* mode (*Bird Dog*) permits precise integration of the UAV with mission fires and maneuvers and realtime decisionmaking about how to best apply the UAV based on the course of mission events. Once UAV task decisions are made, they are immediately implemented and modified in realtime. These flexibility and responsiveness characteristics are operationally attractive but also introduce mission and resource complexity. The coupled mode requires that the mission team include at least one aircraft capable of, or at least compatible with, the particular combat mission's requirements<sup>4</sup> equipped with the technology and manned with a trained crew that can control the UAV and exploit its inputs.<sup>5</sup> This incurs the costs of specially configured aircraft and the

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<sup>3</sup>This anomaly (of the associated mode providing the lowest level of integration with the combat aviation missions while, at the same time, providing the greatest potential for supporting other combat requirements) emphasizes the need for comprehensive operational effectiveness analyses not only at the high-resolution mission level but also at the broader levels that address force availability and competing operational requirements across division, corps, or theater.

<sup>4</sup>The aircraft need not be *fully* mission capable (e.g., for an attack mission it need not be armed), but it must be able to operate in the same tactical regime (e.g., NOE) of the mission aircraft and be closely compatible with speed, range, and endurance requirements dictated by the mission.

<sup>5</sup>By "exploiting" the UAV inputs, we mean that the images the UAV provides are studied and interpreted for content. The content is used to make mission decisions as well as to determine the immediate UAV taskings, i.e., what it should be told to do next.

manning and training implications of specialized crews, and also could affect team size.

While most, if not all, of the technological elements required to operate a UAV in the coupled mode very near the earth (e.g., terrain avoidance, digital mapping, precision location and movement, remote sensor imaging, automated and operator interactive control mechanisms, etc.) exist and are functioning in other contexts, it would be necessary to tailor and probably enhance them to the specific requirements of this application. The availability of such capability would depend both on technological difficulties encountered and programmatic decisions.

## Doctrinal and Operational Impacts

- **New tactics, techniques, and procedures**
- **Coupled integration of UAV likely requires another aircraft on mission team to control UAV**
  - Work load factor too intense to perform team and UAV actions
  - Team too small to absorb loss of team member (e.g., scout recon)
- **Increased team size**
  - Increases physical and electronic activity in operating area
  - Increases opportunities for enemy detection and engagement
  - Changes mission C2 calculus
- **Must be overcompensated for by positive impact on mission effectiveness**
  - Greater achievement of mission objectives
  - Increased team survivability

For all of the integration modes, new tactics, techniques, and procedures for planning and executing the missions would have to be developed to maximize the benefits of integrating a UAV and to minimize the impacts of the additional mission team complexity, coordination, and general work load that could affect team cohesion. With regard to increasing the team size to utilize the coupled mode, we observe that, in general, the fewer aircraft that are needed on a mission, the better from both the operational and resource management standpoints.<sup>6</sup> Hence, maintaining or decreasing mission team size while achieving better or equal operational results would be a *goal* for designing UAV systems to execute the coupled UAV mode and a *measure* of the mode's desirability. Were it necessary to increase the team size to accommodate the UAV integration, the operational and resource management aspects would have to be carefully analyzed to determine the overall net operational effect.

<sup>6</sup>For combat missions normally conducted by a team of two or three aircraft that depend heavily on stealthy maneuvers (e.g., scout and reconnaissance), increasing the team size to integrate a coupled UAV could significantly affect tactics, survivability, and mission performance because of the increase alone.

## UAV Operating Environments

- **Overhead**

- Several thousand-foot altitude above ground level
- Depends on altitude and low signatures for survivability
- Provides loosely correlated movement; vertical view sensing
- Permits autonomous or semiauto control; fixed-wing or VTOL

- **Near earth**

- Combat aviation team NOE, low terrain following environment
- Exploits terrain masking to enhance survivability
- Permits close correlation movements; same-plane sensing
- Requires NOE comm and high agility/maneuverability
- Probably requires precision semiautonomous control and VTOL

- **Mixed**

- Near earth or overhead depending on operational needs
- Probably requires auto & precision semiauto control
- Benefit from variable geometry (VTOL/FW) vehicle capability

In principle,<sup>7</sup> an advanced UAV integrated into a combat aviation mission could operate overhead above the mission's area of operations, near the earth like the mission team, or in a combination of those two environments as appropriate to requirements during different phases of the mission or operational conditions. Some important basic operational characteristics of these environments are outlined above that indicate that the overhead and near-earth environments pose different system design and tactical challenges with respect to survivability, mission correlation, sensing phenomena, and flight dynamics.

We further note here that the overhead environment places lower technological demand on UAV flight characteristics and control mechanisms since it lies entirely in the clear air mass, and both fixed-wing (FW) and VTOL UAVs can fly there; but the overhead flight altitude places the UAV in persistent line-of-sight of enemy air defenses, which could affect survivability against advanced air defense systems and adds to mission command and control complexity because it flies within the

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<sup>7</sup>Depending on system designs and performance characteristics chosen to be developed, the evolution of threat environments, force structure decisions, and other exogenous factors.

joint air-space control zone, and its sensors would be subject to interference by lower cloud cover. The near-earth environment requires high-technology control systems for autonomous terrain avoidance and precise terrain-interactive navigation systems and would need high-performance flight characteristics. Although technologically a FW UAV could be designed and equipped to execute terrain-following and contour flight profiles, the greater flight flexibility of VTOL, including NOE, would enhance near-earth operations and also permit the UAV to operate in the same maneuver and operating regimes as the mission aircraft. The capability of a UAV to operate in both the overhead or the near-earth environment would provide mission flexibility and optimization of the UAV's mission capabilities.<sup>8</sup>

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<sup>8</sup>We will discuss later how a variable geometry (e.g., tilt-rotor) UAV appears to be best-suited to provide dual environment capability.

## UAV Sensor Performance

- **Current optical sensors have “resolution” limitations**
  - Affects detection, classification, . . . .
  - Affected by
    - » technological design
    - » atmospheric conditions (rain, fog, humidity, cloud cover)
    - » range and field-of-view
- **Limitations drive tactics and search patterns**
- **IR sensor enhancements are feasible for UAV**
  - Reduce size and weight
  - Improve performance (e.g., double 1st-gen FLIR effective range)
- **Thin phased-array MMW radar technology needs investigation**
  - Size, weight, power, cost, and performance effects

The “first-generation” sensor technology installed on today’s UAVs has resolution levels that limit its effective coverage of the surface from overhead operating altitudes and complicate detection and categorization (classification, recognition, and identification) of objects scanned. For example, first-principle, technology calculations indicate that a first-generation FLIR using an 11°-by-2° “wide” field-of-view (FOV) could not reliably detect targets beyond a slant range of about 5 km.<sup>9</sup> From 6,000 feet above ground level (AGL), this FOV allows the sensor to cover a 900-by 140-meter pattern that can be pointed to cover a 4.6-km radius circular field-of-regard (on the surface ) at the 5-km maximum detection slant range. A 2°-by-2° “narrow” FOV allows reliable classification and recognition at about a 4-km slant range; it has a 140- by 140-meter square FOV pattern across a 3.5-km circular field-of-regard at the 4-km slant range. Hence, a UAV with these example forward-looking infrared (FLIR) characteristics must fly within a horizontal offset distance of 4.6 km to

<sup>9</sup>Note that the calculations are based on a planner view of the object (e.g., front or flank); hence they probably overstate the capability to detect, classify, and recognize objects viewed from high vertical angles. Also note that the sensor FOV example given here does not correspond exactly to the currently fielded UAV sensors but it provides a useful insight into today’s fielded capability.

reliably detect and within 3.5 km to reliably recognize standard military objects from 6,000-feet AGL. Altitudes above 6,000-feet AGL require even closer offsets. Clearly, an overhead UAV cannot function as a "standoff" platform nor as an efficient wide-area search system. These offsets fall well within the lethal range of most air defense missile systems.

Optical sensor performance can be greatly enhanced simply by using known techniques/algorithms to better process the sensor inputs. For example, it is possible to extend effective range (by nearly a factor of two to detect, classify, or recognize) by refining the conventional FLIR sampling to expose details, improve adverse weather performance by suppressing uncorrelated noise, and distill excessive scene content into its salient essence by transforming it to match the eye's characteristics (Zwirn, unpublished). Such enhancements can either extend the operating performance of existing systems or achieve equal capability with smaller, lighter, basically lower-performance systems to preserve limited payload capacity for other functions (e.g., survivability equipment, communications relays, etc.). In a UAV, a modest FLIR could emulate the performance of a larger, heavier, more expensive FLIR.

Finally, to provide the capability to maintain effectiveness when an atmospheric obscuration such as clouds (a particular difficulty when flying overhead) or combat smoke screening intervene between the UAV and the target areas, an alternative system should be considered. Current development of millimeter wave (MMW) systems for the Longbow and the Battlefield Combat Identification System suggests that a small, lightweight MMW radar system might be feasible to develop for the UAV. Recent assessment (Veit and Callero, unpublished) indicates that thin phased-array MMW radar technology could be a starting point for investigating a radar that is compatible with the UAV size and payload.

The main point of this discussion is that the limitations of current UAV sensors do not have to persist into the future. In fact, potential enhancing technology is approaching off-the-shelf status and could be assessed now for operational utility.

## **UAV Survivability**

- **UAV survivability in the operating environment is an essential element for serious consideration of any UAV integration decision**
- **Overhead UAV survivability in mid- to high-threat environments not certain**
  - Test data scant, flawed, and inconclusive
- **Near-earth UAV survivability has not been addressed**
- **Major factors are**
  - Signatures
  - Exposure time

Integrating the UAV into combat aviation missions obviously requires that the UAV can survive in the threat environment in which it must operate. Current UAVs that by design and doctrine fly at airspeeds below 100 knots and maintain constant altitudes between 6,000 and 10,000 feet AGL for extended periods of time are subjected to continuous clear line-of-sight (LOS) out to the maximum firing range of every forward-area air defense system (FAADS) in the world's inventory. This phenomenon calls into question if the UAV could survive in those operating conditions if modern air defenses were present in the mission area. Of particular concern would be the Russian 2-S6 and SA-15 classes of radar-based air defense systems and the advanced infrared optical systems, including the U.S. Stinger missile, which can be widely available from a number of sources. This class of system has proven in previous research and in some cases by practical demonstration to have the ability to engage and destroy comparatively low-signature aerial vehicles at the full range of their missiles.

To date, what few empirical UAV survivability data have been obtained were collateral data from tests designed to investigate other issues and cannot be used for serious survivability assessment. VTOL UAV concepts offer the potential to operate in near-earth conditions using terrain

masking to enhance survivability, but analyses of this operating mode have not been conducted.

## **UAV Survivability (cont)**

- **Improved survivability affected by**
  - Signature reduction
  - Countermeasures
  - Tactics
- **Signature reduction**
  - Materials, emission control, shaping
  - Has cost implications
- **RF countermeasures**
  - Active (jamming and deception) and passive (deception)
  - Deny or degrade range, azimuth, and/or elevation info
  - Signal specific sensitivities
  - Requires threat warning (radar, missile launch)
  - ECCM uses signal modification; common on modern radars

## **UAV Survivability (cont)**

- **IR countermeasures**
  - Active (flares) and passive (electronic deception)
  - Disrupt fire-control solution in azimuth and/or elevation
  - System-specific sensitivities (imaging, nonimaging)
  - Requires missile-launch warning
- **RF and IR countermeasures difficult to maintain effectiveness because of**
  - Specificity of threat system characteristics
  - Expanded scope of fielded systems we may face
  - Explains ECM technology delays, failures, and false hopes

The usual approaches to increasing survivability apply to the UAV—signature control, active and passive countermeasures, and tactics. Signature control can result from the use of materials and shapes that have low radar reflectivity and the dissipation and shielding of the UAV's heat emissions. Each of these enhancements can incur penalties such as increasing acquisition and maintenance costs, reducing payload, or restricting flight performance.

Countermeasures designed to deny an air defense system from either acquiring, tracking, firing, or guiding a projectile in its engagement cycle can also effectively increase survivability. Such countermeasures can be employed against radar and infrared systems both actively (e.g., radar jamming or flare ejection) or passively, using deception techniques. A prime problem with countermeasures in general has been the difficulty of maintaining the advantage over a determined enemy trying to defeat them, a situation that is exacerbated by the expanded types of air defense systems that we may find employed against us in future, including products of our own and of our cold-war allies. Countermeasures also incur penalties in cost and maintainability and decreased payload, particularly since a countermeasure must be keyed by a warning system identifying the threat, such as radar lock-on or missile launch.

Tactics can also enhance survivability, although a low-performance, slow-flying UAV at altitude would not be expected to use tactics to avoid engagement although even simple changes of heading and altitude can reduce the effectiveness of optically aimed guns. Tactics of particular interest are near-earth or NOE flight regimes that utilize terrain, foliage, or even cultural object masking to decrease exposure to air defenses and increase the complexity of their firing solutions. A VTOL UAV could conceivably conduct such flight profiles using a combination of a high-fidelity terrain map, obstacle avoidance equipment (e.g., radar), and semiautomatic maneuver control under the direction of a human operator.

## **UAV Survivability Conclusions**

- **An in-depth analysis of the survivability issue is a major requirement for determining UAV policy**
  - A combination of signature reduction, countermeasures, and tactics will likely be needed
  - Determining that combination would be the goal
- **If UAVs cannot achieve acceptable survivability levels in the most demanding threat environments, they may still play important roles selectively confined to low-threat areas**

A comprehensive analysis of UAV survivability should be a high-priority effort in the pursuit of a well-grounded UAV policy. Initially, the analysis should be conducted with simulations representing both laboratory and operational environments under a variety of conditions, including current characteristics and a full range of feasible survivability-enhancement concepts. VTOL UAV use of near-earth and NOE flying techniques should be simulated and analyzed for survivability. When the opportunity occurs to conduct field tests and collect empirical data, the simulation experiments and results can provide guidelines to efficient live test designs and, in turn, the empirical data provide inputs to calibrate the simulations.

Determination should be made about which operational environments the UAV could contribute importantly to military objectives given different levels of survivability possible in the different environments. Even UAVs that cannot survive in the most severe environments (as many aircraft cannot) may be able to play important roles in future military operations that feature less-capable air defense threats or have phases (e.g., prior to commencement of combat) when the enemy may not be expected to employ its high-performance air defense resources.

## **VTOL vs non-VTOL**

- **VTOL UAV**

- Provides more operating compatibilities with Army aviation
- Provides increased basing flexibility
- May be capable of flying NOE (to be confirmed)
- Conducive to coupled integration (Pilot Fish)
- Provides tactical options necessary for survivability enhancement

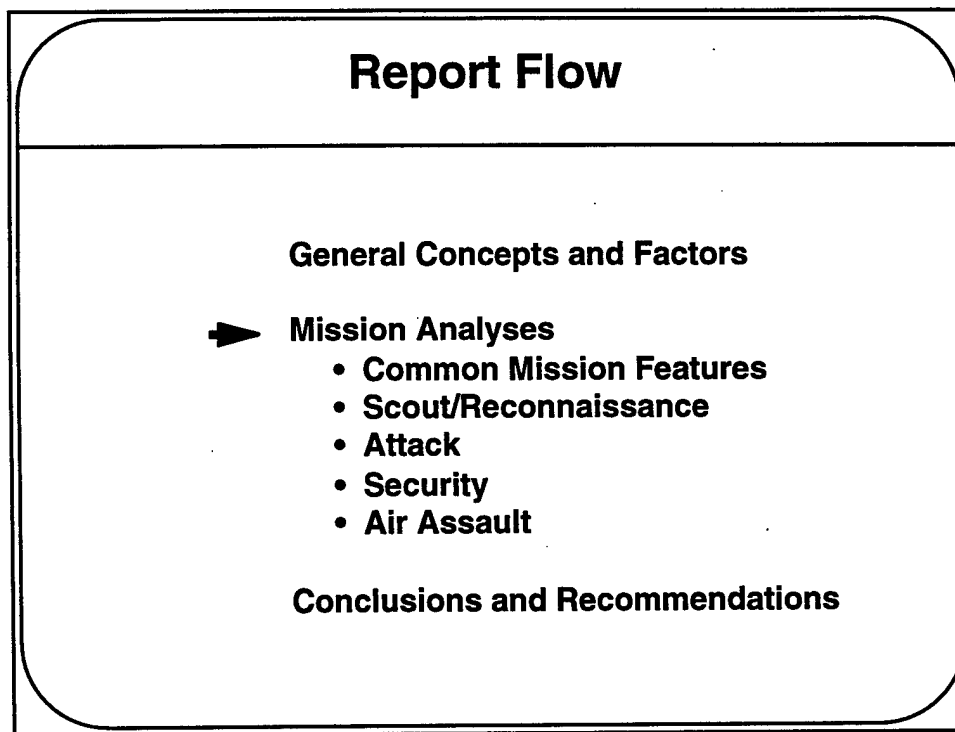
- **The tilt-rotor UAV design subsumes non-VTOL**

- Can operate in the overhead environment
- Can fly at high speed
- Can have low signature levels
- May cost about the same (to be confirmed)
- Apparently exceeds other pure VTOL concepts in terms of speed, range, and compatibility

The issue of whether to develop and acquire VTOL rather than FW UAVs to support an essentially all-VTOL Army aviation force seems to arise because the current UAVs are low-technology FW aircraft with few unknowns, while the newly emerging, more technologically complex VTOL configurations raise a host of developmental risk and cost questions. The apparent operational advantages of VTOL indicated above are significant, particularly those of the tilt-rotor design, which currently exceeds FW UAV performance at altitude and also provides the very low level capability discussed earlier. The Eagle-Eye tilt-rotor UAV prototype developed under the Joint UAV program for Navy shipboard operations demonstrates the feasibility of a variable-geometry UAV and provides a concept exploration vehicle for test and evaluation. Its apparent ability to use the same basing modes, to operate in the same flight regimes, and to fly the same maneuvers as the combat aviation mission teams affords close coordination of all phases of integrated missions.

The tilt-rotor design appears to be a potential contender in the Army's UAV policy decisionmaking process since it combines the best features of FW and VTOL vehicles. Initially, it should be subjected to comprehensive operational analyses to determine its feasible flight regimes under different control modes and its operational effectiveness in a full range of

UAV mission requirements, including, but not limited to, integration with the combat aviation missions. Concomitantly, the programmatic aspects of its development and acquisition should be investigated.



Now that we have reviewed some of the main issues affecting general UAV performance, we turn our attention to each of the combat aviation missions of interest. We first discuss features of the missions that are essentially common to all of them and then focus on the details of each mission, seeking to identify high-payoff opportunities.

## **Common Combat Aviation Mission Features**

- **Intelligence-based mission planning**
- **Team tactics and operation; home base or FARP**
- **Detection avoidance (NOE, terrain masking) ingress to operating area**
- **Priority consideration to air defense locations and realtime detection & recognition**
- **Detection avoidance (NOE, terrain masking) egress from operating area**
- **Recycle from home base or FARP**

Operational aspects that are common to all combat aviation missions are indicated above.

By their very nature, every combat aviation mission intends, or expects, to interact with enemy forces; hence, mission planning emphasizes familiarity with available intelligence relevant to the mission. Of special interest are the location and movements of enemy air defenses and other force elements along ingress and egress routes and in the mission's operating area, particularly those forces the mission intends to interact with. Combat aviation missions are conducted by a team(s) of helicopters that launch either from their home base or from a forward arming and refueling point (FARP). Standard tactics feature movement patterns affording mutual protection and avoiding detection (especially but not only by air defense units) by making maximum use of terrain masking such as flying NOE. Particular attention is given to detecting and recognizing air defense or other threat systems in time to take appropriate action—avoid or engage. Although the missions are carefully planned, midmission adjustments reactive to enemy contacts, intelligence updates, and changing conditions are typically essential to mission success.

## UAV Contributions to Common Mission Features

- **Pre-mission surveillance of mission area**
  - Determine location of enemy systems affecting ingress/egress routes and in operating area
  - Provide target info for attack/scout/recon/security missions
  - Implies “Associated” integration of “Overhead” UAV
  - Requires extensive diversionary operations
- **Ingress surveillance of route and operating area; egress surveillance of route**
  - Determine realtime location of enemy systems affecting ingress and egress routes and the operating area
  - Requires “Dedicated” or “Coupled” integration
  - “Overhead” greater range? “Near Earth” better survivability? Implies “Mixed” mode most effective?
- **Mission time C3 relay node**
  - “Overhead” or “Mixed” mode with any integration technique

The better the mission can be planned and the earlier the mission commander can be alerted to changing conditions during mission execution, the greater would be the chance of success and low attrition. Hence, an important contribution that a UAV could make to any combat aviation mission would be to provide intelligence *that would not otherwise be available, timely, or accurate* during both mission planning and execution. UAV surveillance of the mission area and potential ingress and egress routes shortly prior to mission planning could be conducted using the associated mode employing deception tactics to avoid alerting the enemy to the pending mission. During mission execution, UAV surveillance of the ingress route, operating areas, and egress route in advance of the aviation team movement would provide a basis for realtime decisionmaking; either the dedicated or coupled mode could support this activity. Finally, a UAV communications relay node could contribute importantly to mission outcomes in operational situations that depend on reliable command and control interactions not directly achievable because of range or terrain interference.

Although these contributions to common mission features generally apply to all combat aviation missions, they affect the missions differently and their optimal execution is mission-dependent. For example, UAV surveillance to accurately locate intended targets and reconnoiter battle

positions could affect the outcome of a deep attack mission to a much greater extent than it would a security mission, say, because deep attack missions have much less flexibility and less room for error than the relatively free-form and reactive security missions. Also, the deep attack mission may well require the precision and responsiveness of a coupled integration mode, while the dedicated or even associated mode may be adequate for a security mission. This observation again emphasizes the need for detailed analyses to determine whether and how UAV integration can best support the combat aviation missions.

## **Scout/Reconnaissance**

### **(Basic Combat Aviation Mission)**

- **Team: 2 scouts & 1 overwatch OR 2 armed scouts**
- **Tactics in operating area**
  - Reconnoiter preassigned areas (e.g., NAIs) or routes
  - Bounding maneuvers; NOE, mask/unmask, terrain exploitation
  - Scan area with sensors (IR, TV, MMW radar) to detect systems
  - Timeliness and precision of target cueing aid contacts
- **Actions on contact**
  - Attempt to classify, recognize, and identify contacts
  - Develop the contact area; determine force size/type/disposition
  - Report and proceed
    - If targeting: maintain contact and aid engagement
    - If collecting: proceed to next assigned area
- **Air defense avoidance preferred to confrontation**
- **Endurance/area-coverage key to mission success**
  - Maneuver requirements for effectiveness and survivability

Turning our attention now to assessing UAV integration during the execution of specific combat aviation missions, we begin with scout/recon(naissance).<sup>10</sup>

The primary scout/recon mission activities are shown above. The scout/recon mission functions typically begin at the perimeter of the enemy's main forces and continue for long periods of time and over sizable areas skirting or behind enemy territory. Hence, mission ingress and egress, per se, typically may not overfly territory occupied or controlled by the enemy and that is covered by air defense systems located behind his main trace.

As noted earlier, the scout/recon team is small (two or three aircraft, depending on currently ongoing doctrinal discussions about how to best employ armed scout aircraft). Missions are designed to reconnoiter specific geographic points, areas, or routes where knowledge of enemy activities is important for targeting or situation assessment. Sightings of

<sup>10</sup>Although scout and reconnaissance missions have distinguishing characteristics, they have sufficiently overlapping main features—finding and reporting enemy force element locations, types, activities, etc.—that we chose to combine them in this discussion.

enemy systems or other indications of enemy presence lead the scout/recon team to develop its understanding of the situation by systematically expanding its observations to provide a comprehensive set of data about the enemy (location, type, movement, etc.). The team reports the information and moves on to the next assigned area.

A scout/recon team employs stealthy maneuver tactics to position itself to see the enemy without being seen and depends more on terrain masking and maneuver than engagement and jamming in dealing with threats to its survival. How completely the area(s) of interest can be reconnoitered on a mission depends on the area's geography, the operating endurance of the scout/recon aircraft, and the tactics that the team must employ to effectively observe the enemy and survive given the characteristics of the aircraft, its signatures, and the capability of its sensors.

## **Scout/Reconnaissance**

**(Potential UAV Mission Tasks)**

- **Share mission activities**
  - UAV makes initial contact; helicopters develop the area; UAV proceeds to next area
  - Helicopters make initial contact; UAV develops the area; helicopters proceed to next area
- **Provide realtime surveillance of assigned areas**
  - Target cueing. Threat system warning.
- **Provide wide-area surveillance of operating area**
  - Situation awareness. Threat system locating.
- **Provide reliable C3 linkage**

As indicated, a UAV could share specific mission activities otherwise performed entirely by the aviation mission team. A UAV could also conduct operations such as realtime surveillance of specific locations of interest for target cueing or broader surveillance of the operating area in the path of, or adjacent to, the scout/recon team's movements.

## **Potential UAV Contributions to Scout/Recon Mission Effectiveness**

- **General enhancement of situation awareness and specific location of potential threat systems**
  - Increases combat aviation team survivability
  - Improves maneuver efficiency
- **Target cueing improves overall mission efficiency**
  - Quicker, more effective OP selection and contacts
  - Ready extrapolation of observations to ground truth
- **Task sharing increases mission effectiveness**
  - Provides capability to optimize manned and unmanned systems application
  - Improves mission efficiency by focusing mission elements on highest-payoff tasks

The potential specific contributions that an integrated UAV could make to scout/recon missions center on assisting the scout/recon team to optimize its mission by providing cues about the locations of enemy systems. The need to move carefully, even in the (unknown) absence of actual threats, affects the speed, range, and, hence, coverage that a scout/recon team can achieve. Also, many areas of interest that the team is assigned to observe contain no enemy systems; while this finding may have importance, the effort invested to determine it detracts from the overall advantage of having a human operator on-scene to assess and exploit actual enemy sightings. These observations suggest that the efficiency, hence effectiveness, of scout/recon missions could be improved with better information about the actual location of threats and target systems so the human operators could devote more of their mission time to scrutinizing and assessing enemy forces. Mission efficiency results in either fewer missions required to provide the scout and reconnaissance needs of a unit, since each mission can achieve more, or shorter mission durations to acquire the same information, both of which result in better aircraft utilization and lower operating costs. A mission efficiency operational (vice resource) benefit could be greater intelligence inputs from an equal level of flying activity. The conflict situation would dictate how best to apply the efficiency.

## Scout/Recon Integration

- **Preferred**
  - Coupled Mode and Overhead and NOE Operation
- **Primary operational focus**
  - Pre-recon areas of interest; threat location/warning
  - Participate in NOE scout/recon activities
- **Factors**
  - UAV survivability
  - UAV sensor technology (imaging, threat warning, . . .)
  - UAV maneuver tactics
  - Communications
  - Scout helicopter UAV control and exploitation capability
  - Requires VTOL UAV

Our assessment indicates that if technology can deliver a UAV that requires only minimal crew attention and input for UAV mission control, the preferred method of integrating a UAV with a scout/recon mission team would be the coupled mode operating the UAV in either an overhead or an NOE regime as the mission requires. In this integration, one of the two scout aircraft would function as the UAV controller/exploiter and command the UAV to perform the pre-recon and threat warning activities from overhead and also control it to perform NOE scout/recon maneuvers normally performed by the team, particularly in high-risk (from air defense) areas to take advantage of the UAV's lower (than the scout aircraft's) signatures.

The coupled integration depends critically on the development of the necessary technology and operator interfaces to minimize the additional work load on the UAV control aircraft crew so as not to increase the team size while maintaining full UAV exploitation and the two-aircraft scout/recon team capability. We consider it operationally untenable to add a control aircraft to a two-aircraft team. The coupled mode provides the operationally significant advantages of employing the UAV as a scout when necessary and of using terrain masking to enhance the UAV's survivability.

It appears that the highest payoff UAV activities provide the scout/recon team with is the information necessary to optimize the team's mission efficiency by alerting it to where potential enemy force elements and threat systems are (and are not). These activities would also independently augment intelligence collection. Clearly, overhead UAV operations would be conducted in such a manner as not to alert the enemy to the position and movement of the scout/recon team.

To realize the full operational advantages of the coupled integration mode, a VTOL UAV would be required.

## **Scout/Recon Integration Alternative**

- **Alternative**
  - Dedicated Mode and Overhead Operation
- **Primary operational focus**
  - Pre-recon areas of interest; threat location/warning
- **Factors**
  - UAV survivability
  - UAV sensor technology (imaging, threat warning, . . .)
  - UAV maneuver tactics
  - Communications
  - Scout helicopter image receiver

An alternative integration would be to apply the dedicated mode for UAV control and employ the UAV overhead. The dedicated integration mode dictates the overhead operation both because of the expected difficulties (e.g., continuous command and image feedback communication requirements and realtime responsiveness) associated with NOE mission control and, also, of the need to maintain long distance communications between the control station, the UAV, and the team wherein the UAV would provide the communication relay link.

The dedicated mode maintains responsive control of the UAV's position and activities, relieves the team from the realtime control burden, and avoids the untenable addition of a UAV control aircraft to the small scout/recon team. This alternative would be particularly attractive until the aforementioned mission control technology (the qualifier for the preferred integration) was fielded that minimizes mission control work load or if that technology were not developed.

This alternative could be used selectively when the air defense threat and atmospheric conditions allow overhead operation and when employing the UAV as an NOE scout would not importantly enhance mission results and survivability.

## **Attack (Deep Operations)**

### **(Basic Combat Aviation Mission)**

- **Team: 5 AHs and 3 Armed Scouts (or 3 & 2)**  
**Battalion operation with team rotation/correlation**
- **Prespecified operating area, targets, objectives**
- **Tactics in operating area**
  - NOE final approach to battle positions; mask/unmask tactics
  - Scouts use sensors to find/confirm targets and assign targets to shooters to engage
  - Timely and precise target cueing helps to find targets
- **Air defense avoidance preferred to confrontation**
  - but Air Defense units are highest-priority targets in OA
- **Station time important to mission success**
  - Affected by efficiency of target development
  - Affected by transit optimization

We selected deep operations because they present the most demanding attack mission scenario. The attack teams must penetrate deep into enemy-controlled territory, assess the target situation, assume effective battle positions, engage the assigned targets, and then egress. Deep attack missions are typically, but not necessarily, conducted under cover of darkness to neutralize optical air defense systems and minimize visual detection. They ingress and egress using high-speed, low-level contour flight. In the operating area, the attack team's scouts locate and confirm the suitability of targets, either engage the targets themselves or assign them to other team members to engage, and laser designate the target for terminal flyout of laser-guided missiles, if appropriate. The mission is characterized by a critical need to remain in the target area a minimum amount of time both to increase team survivability and to accommodate aircraft endurance limitations. Although the attack team has the capability to engage air defense systems on ingress and egress, avoidance is preferred; however, in the target area, engagement of air defense systems is the highest priority.

## **Attack (Deep Operations)**

### **(Potential UAV Mission Tasks)**

- **Provide mission-time surveillance of target area**
  - Battle position clearance
  - Situation awareness
  - Threat system warning
- **Share or assume scout role**
  - Provide target location and imaging for engagement decisionmaking
  - Laser designate for laser-guided Hellfire
- **Provide wide-area surveillance of operating area**
  - Situation awareness
  - Threat system locating
- **Provide reliable C3 linkage**

Potential UAV tasks as an integrated part of the deep attack mission are as indicated. Also, the deep penetration through hostile territory emphasizes the importance of the ingress and egress route surveillance tasks discussed earlier. Providing current information during the final planning phases and realtime information throughout the execution of the mission is a task well suited to the UAV's intended capabilities.

## Potential UAV Contributions to Attack Mission Effectiveness

- **General enhancement of situation awareness and specific location of target and threat systems**
  - Improves maneuver efficiency
  - Avoids/reduces target area adjustments
  - Increases combat aviation team survivability
- **Target locating/imaging improves mission efficiency**
  - Supplements scout element
  - Allows more rapid engagement
  - Reduces attrition
    - » Advanced UAV designs expose lower signatures, particularly when supporting all-Apache teams
    - » More rapid engagement reduces exposure time in target area

The defining characteristics of a deep attack mission are the extended penetrations (e.g., more than 100 km) within enemy territory and the high-value nature of the deep attack targets, which are almost always well defended. These characteristics make deep attack the highest-risk combat aviation mission and the one that is most affected by post-planning changes in the operational situation, particularly at the target area. Deep attack targets feature movement as a complicating element. They are either mobile weapon systems or contain mobile systems (e.g., assembly areas and fuel heads). Hence, a key potential contribution to overall mission effectiveness that an integrated UAV could make is to provide the mission commander with continuous current information about the critical elements of the target array and its defenses so that detailed mission adjustments can be made as early into the mission as possible to achieve operational objectives. Once the team assumes initial predetermined battle positions, adjustments and uncertainty introduce undue risk to mission success and survivability. Near-realtime information about the location, movement, and disposition of the target array and of enemy force elements that could affect ingress and egress may determine success or failure of a deep attack mission.

During the short, intense engagement phase, a UAV could assist in focusing scouts on targets, particularly moving targets, or assume some scout functions if it were properly equipped.<sup>11</sup> Such scout support could reduce overall attrition in two ways. One, because an advanced UAV would expose lower signatures to the air defenses than a scout aircraft would, it would thereby reduce the chance of a fatal enemy engagement; and two, if its participation increased the engagement rate of the attack helicopters so the team could complete the mission and depart the high-threat area sooner, it would thereby lessen exposure to attrition.

The degree to which these potential contributions could actually be achieved would need to be carefully investigated by comprehensive combat analyses.

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<sup>11</sup>For example, if it had a laser ranger/designator to precisely determine target location and target hand-off capability to relay it to a shooter.

## Attack Mission Integration

- **Preferred**
  - Coupled Mode
  - Overhead advanced recon of ingress/egress/target area
  - Near earth/NOE in the target area
- **Primary operational focus**
  - Advance recon of ingress, egress, and target area
  - Threat location/warning
  - Targeting
- **Factors**
  - UAV survivability
  - UAV sensor technology (imaging, threat warning, . . .)
  - UAV maneuver tactics, speed, and deception
  - Communications
  - Team member UAV control and exploitation
  - High-speed VTOL UAV required

Our assessment indicates that the preferred method of integrating a UAV with a deep attack mission would be to apply the coupled mode for UAV control and employ the UAV overhead while ingressing and egressing, and near-earth and NOE during the engagement phase. We consider that a battalion-sized mission can readily absorb another helicopter manned and equipped to execute coupled control of the UAV; even an eight-aircraft attack team could add such an aircraft (or assign the task to one of the three scouts) without compromising the team's integrity or survival.

If the UAV can survive and its sensing technology can operate effectively from the overhead flight regime, overhead operation also provides flexibility and responsiveness with respect to finding radar threats<sup>12</sup> that affect the attack teams during ingress and egress, and for reconnaissance of the target area before the attack teams commit to battle positions and tactics. Overhead operation also allows the UAV to fly at maximum speed to perform maneuvers required to support the fast-moving helicopters, for example, to cover the ingress and then dash ahead to reconnoiter the

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<sup>12</sup>Recall that deep attack missions are normally conducted at night; hence, radar air defenses are the only real threats to fast-moving helicopters, i.e., optical air defense systems are not generally effective.

target area before the attack teams make their approach. Exacerbating the speed issue is the need for the overhead UAV to perform deceptive maneuvers so the UAV does not become a "stalking horse" for enemy radars to track the undetected teams' flight path, predict the target area, and alert the local air defense systems. Such deceptive maneuvers would greatly lengthen the UAV's flight profile and, hence, require high speed to maintain an effective position with respect to the attack teams. What an effective speed differential would be needs to be determined by comprehensive simulation and analysis, but it appears to exceed twice the operating speed of the attack teams.

Once in the target area, the UAV would transition to near-earth or NOE where it could provide direct, integrated support of the scouts' targeting activities as described above. With regard to the UAV descending to participate in the attack phase, the target area is well defended; hence, the UAV's survivability from directly overhead would be very low. An ameliorating condition could be that the air defenses would concentrate on the attacking aircraft and ignore the UAV, but there should be sufficient time and perceived need by the enemy to shoot down the UAV without detracting from their attack team engagement efforts.

Hence, attack mission integration appears to require a high-speed VTOL UAV (VTOL to operate NOE and high speed to satisfy the overhead maneuver conditions just described). VTOL would also provide capability to support the attack team when either advanced air defenses or weather conditions interfere with overhead operation; the VTOL UAV could fly near-earth with the attack team and still accomplish much of its preengagement phase functions.

We note that, although a VTOL UAV appears to best satisfy mission functions, a survivable, high-speed, non-VTOL UAV could also perform the overhead preengagement functions and then depart the target area until needed to support the egress.

## **Security (Screen & Cover)**

**(Basic Combat Aviation Mission)**

- **Combines features of Scout/Recon and Attack**
  - Team: Correlated Armed Scouts and Attack helicopters
  - Cavalry squadron operation
- **Operating area near to friendly positions/boundaries**
- **Tactics in operating area**
  - Scouts conduct area surveillance; locate and track enemy
  - Scouts or attack helos engage if appropriate
- **Air defense avoidance preferred to confrontation**
  - but Air Defense units are highest priority targets in OA
- **Station time important to mission success**
  - Affected by efficiency of target development

Security missions are economy of force missions conducted to serve one of three general objectives—screen, cover, or guard—so the division's main effort can be directed elsewhere. A screen mission aims to determine if enemy forces are positioned to threaten an exposed sector of a unit's area of operations, such as a flank. A cover mission protects an exposed sector from enemy forces that threaten the sector. A guard mission protects forces on the move such as on road marches. For our assessment, we consider a combined screen (which locates the enemy force) and cover (which ensues from the screen).

Typically, a cavalry squadron conducts security operations. It employs a combination of scout and attack helicopters and ground forces to find and repel limited enemy operations and to delay major enemy activities (e.g., a flanking attack) in the assigned sector. The sector usually, but not always, lies adjacent to the primary friendly forces' positions and may include territory considered to be friendly or neutral. Screen/cover security missions combine the essential elements of scout/recon and attack missions; the scouts locate and assess enemy forces in the area and, if considered appropriate to the mission objectives, armed scout or attack teams engage them.

## **Security**

**(Potential UAV Mission Tasks)**

- **Share reconnaissance role**
  - UAV locates enemy systems; scout helo develops situation
- **Share/assume attack team scout role**
  - Provide target location and imaging for engagement decisionmaking
  - Laser designate for laser-guided Hellfire
- **Provide realtime surveillance of target area**
  - Battle position clearance
  - Situation awareness
  - Threat system warning
- **Provide wide-area surveillance of operating area**
  - Situation awareness
  - Threat system locating
- **Provide reliable C3 linkage**

Potential integrated UAV tasks for the screen-and-cover security mission are similar to those of the scout/recon and attack missions, depending on the specific operations the security mission team is conducting. The UAV could move between tasks as most needed.

## **Potential UAV Contributions to Security Mission Effectiveness**

- **For Scout operations**
  - Target cueing improves overall mission efficiency
  - Task sharing increases mission effectiveness/efficiency
- **For Attack operations**
  - Target locating/imaging improves mission efficiency
  - Reduces attrition
- **General enhancement of situation awareness and specific location of potential threat systems**
  - Increases combat aviation team survivability
  - Improves maneuver efficiency
- **Multiple UAVs could allow a single cavalry unit to screen and cover multiple areas**

The potential UAV contributions to an integrated security mission follow those of the scout/recon and attack missions. Since much of the mission is conducted over territory not occupied by enemy forces, the UAV contributions center on directly sharing mission team tasks, providing less independent wide-area input.

Another contribution that integrated UAV operations could make would be to allow multiple security areas to be assigned to a single cavalry unit. Since security areas are typically well defined and limited in size, a UAV could monitor each area. The control and exploitation unit would determine the presence of enemy forces and their activities, and the cavalry unit could respond as needed to circumstances arising in a particular area.

## Security Mission Integration

- **Preferred**
  - Coupled Mode
  - Overhead recon of area
  - Near earth/NOE for engagements
- **Primary operational focus**
  - Recon assigned area
  - Threat location/warning
  - Targeting
- **Factors**
  - UAV survivability
  - UAV sensor technology (imaging, threat warning, ...)
  - Communications
  - Team member UAV control and exploitation
  - VTOL UAV required for NOE

The most extensive integration of a UAV with the screen-and-cover security mission would follow the scout/recon and attack approach to provide both support for the scout/recon activities of finding enemy forces in the area or monitoring their movements and disposition, and for engaging them if necessary. Since a security mission is conducted by at least a troop of approximately eight (yet to be decided upon) armed scout helicopters and possibly a squadron (three troops), the mission team could readily incorporate a scout equipped and manned to control the UAV in the coupled mode. In fact, for a stable situation, the team could send only the UAV and wait on the ground until some significant enemy activity demanded more on-scene attention. Furthermore, a cavalry unit can be assigned to multiple areas, each being overseen by a UAV, and respond as necessary in whichever area enemy activities demand attention.

The factors affecting integration parallel those seen in other missions, including a VTOL UAV to conduct NOE operations.

## **Security Mission Integration Alternative**

- **Alternative**
  - Dedicated mode
  - Overhead recon of area
- **Primary operational focus**
  - Recon assigned area
  - Threat location/warning
- **Factors**
  - UAV survivability
  - UAV sensor technology (imaging, threat warning, . . .)
  - Communications

An alternative integration eliminates the UAV participation in the engagement phase of the mission and generally simplifies the process and requirements. It features the dedicated mode of control and overhead reconnaissance support. It eliminates the need for VTOL and a mission team member designated for UAV control.

## **Air Assault**

**(Basic Combat Aviation Mission)**

- **Team: UHs with armed scout and AH escort; numbers dictated by assault force size**
- **Prespecified Landing Zone (LZ) selected for unopposed/lightly opposed entry**
- **Tactics in LZ area**
  - UHs approach LZ using low contour flight profiles
  - UHs land or hover and off load with precise timing/coordination
  - Escorts provide covering fires and perimeter defense
  - Mission aircraft depart area within minutes
- **Threat avoidance preferred to confrontation**
  - but Air Defense units are highest-priority targets in OA

The air assault mission is conducted to put dismounted soldiers and equipment on the ground in a landing zone (LZ) located in enemy-controlled territory. The LZ is selected to minimize the risk of enemy action against the aircraft or soldiers during the landing operation. The assault helicopters carrying the troops and equipment are escorted by scout and attack helicopters<sup>13</sup> to reconnoiter the route and engage enemy forces posing an immediate threat to the assault helicopters. Tactics in the LZ are as indicated.

Note the close parallels to the deep attack mission: high-speed, low-level ingress and egress and engagement potential in the LZ area. Attack missions differ because engagements are certain in their target area; although not certain, the air assault escort force must be as equally prepared to conduct them.

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<sup>13</sup>And probably further supported by close support Air Force aircraft as well to prepare the LZ with fire prior to the assault force arrival and assist the attack helicopters in defending the area.

## **Air Assault**

**(Potential UAV Mission Tasks)**

- **Provide advance and realtime surveillance of LZ**
  - Situation awareness
  - Threat system warning
- **Provide wide-area surveillance of operating area**
  - Situation awareness for ground force commander
- **Provide reliable C3 linkage**

The air assault mission is characterized by lengthy ingress and egress flights with short, intense, off-loading activity in the LZ. In addition to supporting the mission planning and transit phases, the integrated UAV could provide realtime surveillance at the LZ in advance of the assault force and during the LZ phase and participate in the attack helicopter engagements, if necessary.

## **Potential UAV Contributions to Air Assault Mission Effectiveness**

- **General enhancement of situation awareness and specific location of all enemy forces**
  - Increases ground force survivability in air and on the ground
  - Increases combat aviation team survivability
- **If entry is opposed, UAV contributes as in attack mission**

The main contribution of an integrated UAV with an air assault mission is to provide realtime information about *all* enemy forces along the ingress route and in the LZ area. Unarmed assault helicopters are highly vulnerable to small arms as well as air defense weapons in the low-level contour flight paths (not NOE) they must fly and are the prime targets (as opposed to the escorts) of enemy ground systems that observe their passage and can engage them.

## Air Assault Mission Integration

- **Preferred**
  - Coupled Mode
  - Overhead advanced recon of ingress/egress/LZ
  - Near earth/NOE for engagements
- **Primary operational focus**
  - Advance recon of ingress, egress, and LZ
  - Threat location/warning
  - Targeting
- **Factors**
  - UAV survivability
  - UAV sensor technology (imaging, threat warning, . . .)
  - UAV maneuver tactics, speed, and deception
  - Communications
  - Team member UAV control and exploitation
  - High-speed VTOL UAV required

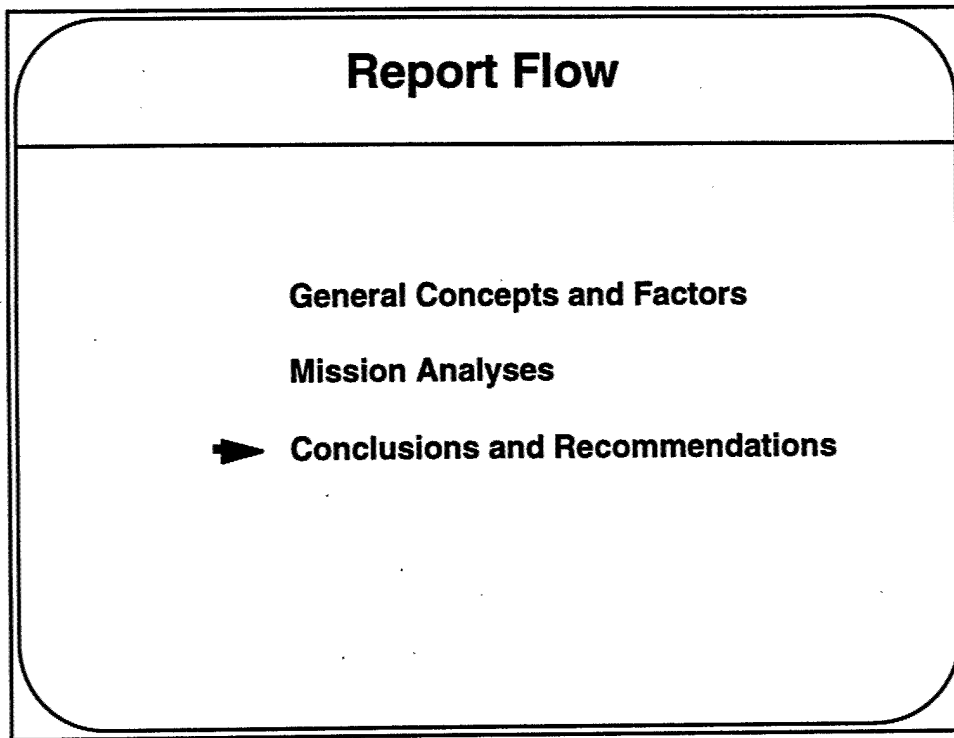
Since the air assault mission closely parallels features of the deep attack mission, the preferred integration, operational focus, and factors are essentially the same. We consider that the pace of the mission requires the coupled mode employing the UAV overhead while ingressing and egressing, and near-earth/NOE during engagements in the LZ area. The escort force can readily include a helicopter manned and equipped to execute coupled control of the UAV. The observations with regard to operating regimes and high-speed VTOL requirements, and UAV deception made in the deep attack discussion, apply to the air assault mission. The main difference between the two missions is that the attack mission expects to encounter heavy defenses, while the air assault mission LZ is selected to preclude or minimize an enemy defense; hence, the UAV operation in the LZ area may capitalize on the lightness of air defenses and not have to descend to the near-earth/NOE regime. If such were the case, a high-speed, non-VTOL UAV could operate as effectively as a VTOL.

## Mission Integration Summary

| Potential UAV Contribution                        | Scout/<br>Recon<br>Mission | Deep<br>Attack<br>Mission | Security<br>Mission | Air<br>Assault<br>Mission |
|---|----------------------------|---------------------------|---------------------|---------------------------|
| Premission Surveillance                           |                            |                           |                     |                           |
| Ingress/Egress Support                            |                            |                           |                     |                           |
| Mission Task Sharing                              |                            |                           |                     |                           |
| Realtime Surveillance<br>Target/threat cueing     |                            |                           |                     |                           |
| Reliable C3 Linkage<br>(if overhead ops feasible) |                            |                           |                     |                           |

|  |                |
|--|----------------|
|  | Not applicable |
|  | Limited use    |
|  | Extensive use  |

In summarizing the potential contributions from integrating UAVs with combat aviation missions, this chart depicts how the various contributions are expected to apply to each of the missions. Clearly, all missions appear to benefit, with the scout/reconnaissance and deep attack missions particularly amenable to integrated operations. The caveat "if overhead operations are feasible" with regard to helping with reliable command, control, and communications reflects the need for the UAV to operate in the overhead mode to sustain the linkage and pertains to the current uncertainty about survivability.



We now turn our attention to the conclusions that arise from the previous material and offer our recommendations.

## **Preliminary Assessment Conclusions**

- **Integrated UAV could significantly enhance all combat aviation missions**
  - Mission performance
  - Mission efficiency
  - Survivability
  - Aviation resource utilization
- **Coupled (Bird Dog) integration mode dominant**
- **Advanced UAV characteristics needed**
  - Expanded MEP
  - Better sensor performance
  - Survivability enhancements
- **High-speed VTOL UAV configuration provides essential capabilities**

Our preliminary assessment of the tactical UAV leads us to expect that combat aviation missions could be significantly enhanced if a UAV was integrated as a full member of the mission team. Effectiveness would improve both in the results that the mission achieves and in the efficiency with which the aviation systems can be employed. Survivability of the aviation systems may also result both because UAV information can be used to avoid or destroy air defenses and because of reduced exposure on the battlefield as a result of the more efficient manner in which the mission can be conducted. Efficiency also leads to better overall aviation resource utilization, which would increase the resources available for other missions.

The coupled integration mode that captures the essence of the Bird Dog concept predominates in the missions we assessed. Two of those missions, deep attack and air assault, cannot be integrated any other way; the coupled mode is preferred for the security mission, particularly if the UAV can participate in engagements; and while not necessary for the scout/recon mission, the UAV can be effectively used for some secondary functions only in the coupled mode.

To realize the benefits of integrated UAV operations, a number of technological improvements need to be incorporated into the advanced

UAV designs of the future. Compared with today's capability, the mission equipment package (MEP) needs expanding to contain more sensors and functions, including radar warning that can be relayed to the mission team,<sup>14</sup> laser ranger/designator, digital mapping (for VTOL), and perhaps MMW radar. Also, the imaging sensor needs enhancement to increase the scope and precision of its viewing area. And features must be added so that the UAV's survivability is highly likely in the face of advanced air defenses and virtually assured when operating in lesser, more likely air defense environments.

Finally, the VTOL near-earth and NOE flight regime appears repeatedly in our assessments as necessary to mission accomplishment, both to support the operation and to use terrain masking to survive in high-threat areas. To maintain its effectiveness in supporting high-speed helicopter transits, ingresses, and egresses, the UAV must have even greater speed capability, perhaps two to three times as great as that of the helicopters.

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<sup>14</sup>The threat warning functions discussed for each of the missions primarily addressed radar-based threats. From an overhead position, a UAV with radar warning and homing capabilities can detect and estimate the location of radars well before the low-flying mission team would pick up the emissions. Such advanced warning would reduce the chance that the team would unwittingly fly into a serious threat condition as they cleared a particular terrain feature, e.g., rounding or overflying a hill.

## **Comprehensive Analysis Recommendations**

- **UAV sensor performance**
  - Detection, classification, recognition capability
  - Atmospheric effects
  - Technology enhancements (size, performance)
- **UAV survivability**
- **Measuring changes to mission effectiveness**
  - MOEs and scope of operational environments
  - Analysis methodology and input data
  - Doctrinal and operational impacts
- **Near-earth operation feasibility**
- **Airborne interface system requirements**
  - Functions, technology, packaging, work load, . . .

The preliminary assessments and conclusions presented in this briefing are primarily based on qualitative analyses from which we intended to provide an informed basis for determining the most critical issues that need comprehensive analyses. The first two indicated on the chart, sensors and survivability, were discussed in some detail in the text. For sensors, there is a need to determine the expected performance levels of the current and advanced technology of UAV primary mission sensors and their operational implications. Operational implications include required proximity to target, search techniques and area coverage, likelihood of detection through identification, and the value of autonomous or semiautonomous capability. For survivability, there is a need to determine the conditions under which a UAV could and could not survive to successfully operate in a combat environment. Conditions of interest include concepts of operations, signatures, mission equipment, and threat composition.

We will now look more closely at measuring effectiveness, near-earth operations, and the airborne interface system.

## Measuring Effectiveness

- **Use existing analytical tools; develop specific techniques as appropriate**
  - Interactive (RAND CAE, AVTB, R&D simulators)
  - Noninteractive (JANUS, CASTFOREM, SAVVIE)
  - Apply without UAV team integration and with UAV alternatives
- **Use/develop appropriate MOEs**
  - Important results may come from small changes
- **Develop/validate input data and subsystem models**
  - Flight dynamics, sensors, signatures, ASE, comm, control, system availability/sustainability, . . .
- **Analyze in**
  - Representative operational environments (heavy and light force operations)
  - Mission and “campaign” analyses

A quantitative analysis of how integrating UAVs would change the operational effectiveness of combat aviation forces is essential to formulating a position on UAV development. It establishes the potential benefits and identifies the technological and operational conditions under which the benefits accrue. Analytical tools exist that could be applied to this task, some needing only minor tailoring to accommodate specific UAV characteristics and integrated mission execution and others needing major changes.

For research on integrated UAV missions, which have little or no practical experience base, operator interactive analytical systems provide an environment to experiment with and develop tactics and procedures before committing them to specific behaviors in an analysis. The available interactive systems include the Aviation Test Bed (AVTB) at Fort Rucker and contractor's research and development simulators, although simulators suffer from combat environment fidelity problems and are not readily adapted to analysis. RAND's Combat Analysis Environment (CAE)<sup>15</sup> probably offers the most adaptive and efficient high-resolution, operator-interactive analytical system available. Noninteractive systems also exist that represent operator behavior with programmed rules that

<sup>15</sup>The CAE is extensively described and referenced in Veit and Callero, unpublished.

reflect stylized decisionmaking (SAVVIE) or low-fidelity, nonreactive behavior (JANUS, CASTFOREM).

Standard analytical procedures can be applied to compare missions without and with alternative UAV integration using a well-developed set of measures of performance and effectiveness. All input data, flight dynamics models, and special subsystem (e.g., UAV sensor) models would need to be validated. Finally, since mission and aviation force utilization efficiencies appear to be a major result of integrated operations, the analyses should be conducted at both the tactical and operational levels, to include campaign analyses to measure long-term effects, efficient use, and increased survivability.

## Near-Earth Operation

- **Coupled near-earth operations appear to offer significant operational advantages**
  - Will require VTOL capability
- **Feasibility of NOE and close terrain following needs to be confirmed**
  - Valid assessment needed in order to consider near-earth operations
- **Contractor (e.g., Eagle-Eye) R&D simulator provides**
  - First-order assessment of feasibility
  - Laboratory for developing control and operations techniques and procedures
  - First-order assessment of work load

A question that needs to be resolved centers on the feasibility, flexibility, and limitations of operating a VTOL UAV in the near-earth/NOE flight regime. Such operations controlled from a tactical aircraft deserve particular attention. Comprehensive analysis requires the use of specially designed simulators that incorporate both the scene displays and control mechanisms used by an operator-controller and the on-board UAV systems such as obstacle avoidance, altitude measuring, and digital mapping required to perform maneuver taskings. Although the mission-effectiveness analyses mentioned above do not have to wait for the results of the near-earth analyses, the information derived from the near-earth analyses can supplement and be used to calibrate the near-earth operations conducted in the simulated environments.

## Airborne Interface System

- **Two environments provide different issues**
  - Command and control aircraft (standoff, on-scene?)
  - Tactical aircraft (on-scene)
- **Function and feature options need to be assessed; costs/benefits of commonality**
- **Need to establish feasibility for tactical aircraft**
  - Packaging, comm, power, weight, . . .
  - Functionality and work load
- **Contractor (e.g., Eagle-Eye) simulator could provide first-order functionality and work load assessment**
  - for both VTOL and non-VTOL concepts

An airborne interface system designed to provide UAV control and image exploitation presents another area for analysis. A thorough investigation of its concepts, functions, equipment/technology, and installation must be done to determine the feasibility and practicality of providing the capability in a tactical aircraft—Kiowa Warrior, Apache, and Comanche—that may, in the coupled mode, control a UAV during a mission. The Aviation Restructure Initiative of February 1993 includes the development of a Common Airborne Control Station compatible with the UH-60. In our assessment, we have assumed that the Common Airborne Control Station would provide the remote UAV control and exploitation functions in the dedicated integration mode and further assumed that the same capability could be provided from a tactical aircraft, primarily one of the mission's scout helicopters. On these assumptions rests the feasibility of the coupled mode and, of course, the Bird Dog concept.

It appears that the investigation initially depends heavily on engineering analysis that would lead to credible use of contractor research and development simulators.

## Summary

- **Integrating UAVs in combat aviation missions**
  - appears feasible
  - offers significant operational and resource benefits
- **Bird Dog (coupled mode) is preferred concept**
- **Technological enhancements needed**
  - sensors, control and exploitation, comm, . . .
- **UAV survivability needs improvement**
- **Tilt-rotor design is operationally dominant**
- **Comprehensive analyses must be undertaken**

This chart briefly summarizes the results of the assessment.

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